Environment Canada Environnement Canada
2022993I DEST PVM EXCH COPY 03
TD 171.5.C3 R43
VOL ISS 83-13
REGIONAL PROGRAM REPORT (CANADA. ENVIRONMENTAL PROTECTION SERVICE. PACIFIC REGION)

Environment Canada | Environnement Canada

Environmental Protection Service | Service de la protection de l'environnement

DEPARTMENT OF ENVIRONMENT
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC REGION

YAKOUN RIVER AND TRIBUTARY STREAMS - WATER QUALITY DATA COLLECTED BY THE ENVIRONMENTAL PROTECTION SERVICE OVER JUNE 1981 TO MARCH 1982

Regional Program Report No. 83 - 13

By

George Derksen

August 1983

ABSTRACT

Three surveys were conducted over 1981-1982 to document the water quality of the Yakoun River, Barbie Creek, Canoe Creek and Florence Creek located on Graham Island, Queen Charlotte Islands. The Yakoun drainage is characterized by water having: low alkalinity, low pH, low hardness, high organic content and high colour. Consolidated Cinola Mines Ltd. have proposed to develop an open pit gold mine within the drainage area studied.

Heavy metal levels of the streams sampled were compared to Environment Canada objectives and U.S. Environmental Protection Agency criterion for the protection of freshwater aquatic life.

The influence of increased surface runoff on water quality was documented during the September, 1981 survey.

RÉSUMÉ

De 1981 à 1982, on a procédé à trois analyses différentes pour déterminer la qualité de l'eau des rivières Yakoun, Barbie Creek, Canoe Creek et Florence Creek situées dans l'ile Graham des Iles de la Reine Charlotte. Le bassin hydrographique de la rivière Yakoun se caractérise par une eau de faible alcalinité, de faible pH, de faible degré hydrotimétrique, de fort contenu organique et de couleur foncée. Consolidated Cinola Mines Ltd. a proposé de développes une mine d'or à l'interieur de la région de drainage étudiée.

En vue de la protection de la vie aquatique en eau douce, on a comparé le niveau des métaux lourds des courds d'eau dans lesquels on a prélevé des échantillons aux objectifs d'Environnement Canada et aux critères posés par l'organisme américain Environmetnal Protection Agency.

Les effets d'un accroissement des eaux de ruissellement sur la qualité de l'eau ont été déterminés lors de l'enquête de 1981.

TABLE OF CONTENTS

		Page
ABSTRACT		i
RÉSUMÉ		ii
TABLE OF CONTENTS		iii
	List of Figures	v
	List of Tables	vi
SUMMARY AND CONCLUSIONS		viii
1	INTRODUCTION	1
2	DESCRIPTION OF STUDY AREA	4
3	MATERIALS AND METHODS	7
3.1	Water Samples	7
3.1.1	Inorganics (excluding metals), Temperature and Flow	7
3.1.2	Total and Dissolved Metals and Hardness	7
4	OBJECTIVES AND CRITERIA FOR THE PROTECTION OF FRESHWATER AQUATIC LIFE	10
5	RESULTS AND DISCUSSION	12
5.1	Water Samples	12
5.1.1	Inorganics (excluding metals), Temperature and Flow	12
5.1.1.1	Total Alkalinity (as $CaCO_3$), Total Acidity (as $CaCO_3$), pH and Hardness (as $CaCO_3$)	12
5.1.1.2	Total, Non-filterable and Total Volatile Residue and Total Organic Carbon	16
5.1.1.3	Conductivity, Tristimulus Colour, Temperature and Flow	18
5.1.2	Total and Dissolved Metals	19
5.1.2.1	Total Mercury and Total and Dissolved Arsenic	21

TABLE OF CONTENTS (Continued)

		Page
5.1.2.2	Total and Dissolved Lead and Zinc	24
5.1.2.3	Total and Dissolved Cadmium and Copper	27
5.1.2.4	Total and Dissolved Chromium and Nickel	30
5.1.2.5	Total and Dissloved Selenium, Aluminum, Iron and Manganese	33
REFERENCES		37
ACKNOWLEDGEMENTS		41
APPENDIX I	RECEIVING WATER QUALITY DATA FOR HEAVY METALS - YAKOUN RIVER AND THREE TRIBUTARY STREAMS	42

LIST OF FIGURES

Figure		Page
1	YAKOUN RIVER AND SAMPLE STATION LOCATIONS	2
2	YAKOUN RIVER FLOWS (WSC080A002), 1981-1982	5

LIST OF TABLES

Table		Page
1	DESCRIPTION OF SAMPLE STATIONS ON THE YAKOUN RIVER AND TRIBUTARY STREAMS	6
2	PRESERVATION AND TREATMENT OF WATER SAMPLES FOR HEAVY METAL ANALYSES	9
3	TOTAL ALKALINITY, TOTAL ACIDITY, pH AND HARDNESS OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS	14
4	TOTAL, NON-FILTERABLE AND TOTAL VOLATILE RESIDUES AND TOTAL ORGANIC CARBON OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS	17
5	CONDUCTIVITY, TRISTIMULUS COLOUR, TEMPERATURE AND FLOW OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS	20
6	MERCURY AND ARSENIC LEVELS OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS	22
7	LEAD AND ZINC LEVELS OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS	25
8	CADMIUM AND COPPER LEVELS OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS	29
9	CHROMIUM AND NICKEL LEVELS OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS	31

LIST OF TABLES (Continued)

Table		Page
10	SELENIUM AND ALUMINUM LEVELS OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS	34
11	IRON AND MAGANESE LEVELS OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS	35

SUMMARY AND CONCLUSIONS

The water quality of the Yakoun River, Barbie Creek, Canoe Creek and Florence Creek was monitored during June and September, 1981 and March, 1982. The objective was to collect background data prior to the development of a proposed goldmine (Consolidated Cinola) on Graham Island.

The alkalinity of the streams measured did not exceed 20 mg/l as $CaCO_3$. The Yakoun River had the highest overall alkalinity ranging between 6.0-15.1 mg/l while Canoe Creek had the lowest alkalinity (0.5-5.5 mg/l). The Yakoun drainage has very little quantitative capacity to buffer acidic discharges. The pH of the streams did not exceed 7.1. Again, the Yakoun River overall had the highest pH ranging between 6.6-7.1 while Canoe Creek had the lowest pH (5.1-6.0). The three tributary streams all recorded pH levels below pH 6, the lower criterion suggested for a high level of protection to freshwater aquatic life. The mean water hardness of the streams didn't exceed 14.1 mg/l (as $CaCO_3$) and with the Yakoun River having the highest levels ranging between 10.9-14.0 mg/l and Canoe Creek the lowest levels (5.0-8.9 mg/l). The waters in the Yakoun drainage are very soft.

The non-filterable residue (suspended solids) levels of the streams were generally below the 5 mg/l detection limit. However, for the Yakoun River stations, suspended solids increased (to a high of 63 mg/l at Yakoun River #3) as a result of increased surface runoff during the September, 1981 survey. A similar increase was not recorded in the three tributary streams. The generally high total volatile residue levels respective to the total residue indicated the organic nature of the system and this was further evidenced by high total organic carbon concentrations. Canoe Creek had the highest total organic carbon concentrations (18-31 mg/l) while the Yakoun River had the lowest (6-17 mg/l). The high colour values for the streams again reflect their organic nature with Canoe Creek being the highest (165-322) and the Yakoun River the lowest (50-122).

In general, total mercury concentrations of the streams were below the detection limit of 0.2 ug/l. In the September, 1981 survey with increased surface runoff, four of thirty-six samples had detectable concentrations (0.23 ug/l - 0.7 ug/l). In order to establish the influence of increased surface runoff on mercury levels in the Yakoun drainage and to be consistent with recommended objectives and criterion, any further water quality work related to mercury in this drainage should use a lower detection limit.

Total arsenic levels of the streams were low and ranged between less than 0.5 ug/l to 2.3 ug/l. These levels are well below the Environment Canada recommended objective of 50 ug/l total arsenic for the protection of aquatic life.

The total and dissolved lead concentrations of the streams were all below the detection limit of 40 ug/l used in June and September, 1981. A lower detection limit in March, 1982 indicated detectable concentrations of total lead between 20-40 ug/l but dissolved lead values were all less than 20 ug/l. Environment Canada recommended a total lead objective for soft water of 5 ug/l for the protection of aquatic life and the U.S. EPA set a criterion of 74 ug/l total recoverable lead as a concentration for soft water (50 mg/l as $CaCO_3$) not to be exceeded at any time for the protection of freshwater aquatic life.

Total and dissolved zinc concentrations were generally at or near the detection limit of 5 ug/l except during the September, 1981 survey when the influence of increased surface runoff was evident. Elevated levels of zinc throughout the survey area on September 11, 1981 (and on September 10, 1981 for Barbie Creek) reflect an influence due to increased rainfall and flows. Barbie Creek had the highest dissolved zinc levels on September 11 with concentrations between 17-20 ug/l. For the same period the total zinc concentrations were between 26-139 ug/l. The dissolved zinc concentrations for the other stations on September 11 were 6-8 ug/l and for total zinc 19-418 ug/l. The highly variable total zinc concentrations (between the three replicates) indicate a non-uniform

dispersion related to increased particulates greater than 0.45 um (as supported by the uniform and low concentrations of the dissolved zinc samples). For total zinc on September 11, 10 of 36 samples exceeded the Environment Canada recommended objective for the protection of aquatic life for softwater of 50 ug/l and 3 of 36 samples exceeded the U.S. EPA criterion of 180 ug/l total recoverable zinc set as a concentration for softwater (50 mg/l as $CaCO_3$) not to be exceeded at any time. Dissolved zinc concentrations did not exceed 20 ug/l at any time and were generally less than 5 ug/l.

Total and dissolved cadmium concentrations didn't exceed the detection limit of 4 ug/l in June and September, 1981 and there was no influence due to increased surface runoff. A lower detection limit in March, 1982 indicated a few samples had just detectable total cadmium levels of 2-3 ug/l but dissolved cadmium concentrations were all less than 2 ug/l. Environment Canada recommended an objective of 0.2 ug/l for total cadmium for the protection of aquatic life and the U.S. EPA set a criterion of 1.5 ug/l total recoverable cadmium as a concentration for softwater (50 mg/l as $CaCO_3$) not to be exceeded at any time for the protection of freshwater aquatic life.

Total and dissolved copper concentrations were generally below the detection limit of 5 ug/l. Environment Canada recommended an objective of 2 ug/l for total copper for the protection of aquatic life and the U.S. EPA set a criterion of 12 ug/l total recoverable copper as a concentrations for softwater (50 mg/l as $CaCO_3$) not to be exceeded at any time for the protection of freshwater aquatic life. In June, 1981, 7 of 36 samples had total copper concentrations between 6-32 ug/l but these were higly scattered i.e. two of the three replicates could be less than 5 ug/l and one as high as 32 ug/l. The reason for this variability is not apparent and was not reflected in the dissolved copper values which were all less than 5 ug/l. In March, 1982 individual total copper concentrations between 6-8 ug/l were recorded while dissolved copper concentrations were less than 5 ug/l.

Total chromium concentrations were generally below the 7.5 ug/l detection limit and all dissolved chromium concentrations were less than the detection limit. Environment Canada recommended a water quality objective of 40 ug/l as total chromium for the protection of aquatic life.

The total and dissolved nickel concentrations were all less than the detection limit of 40 ug/l in September and June, 1981 and 20 ug/l in March. Environment Canada recommended a water quality objective for softwater of 25 ug/l as total nickel for the protection of aquatic life and the U.S. EPA set a criterion of 1100 ug/l total recoverable nickel as a concentration for softwater (50 mg/l as $CaCO_3$) not to be exceeded at any time for the protection of freshwater aquatic life.

Total and dissolved selenium concentrations never exceeded the detection limit of 0.5 ug/l and are below the recommended Environment Canada objective for aquatic life of 10 ug/l.

There were not any water quality objectives found relating to aluminium and for the survey area overall, mean total and dissolved aluminium concentrations ranged between 91 ug/l - 3197 ug/l and 66 ug/l - 621 ug/l, respectively. Mean total and dissolved iron concentrations for the survey area overall ranged between 262 ug/l - 3500 ug/l and 100 ug/l - 1510 ug/l respectively. Barbie Creek, Canoe Creek and Florence Creek had high iron levels with mean total and dissolved concentrations above 1000 ug/l in June and September, 1981. Mean total and dissolved manganese concentrations for the survey area overall ranged between 14 ug/l - 304 ug/l and 10 ug/l - 92 ug/l, respectively.

Water quality characteristics to be considered when assessing the Yakoun River drainage in relation to any mining activity are its low alkalinity, low pH, low hardness and high organic content. These are variables which strongly influence heavy metal chemical form (speciation) and toxicity.

The influence of increased surface runoff is an important factor to be considered when establishing water quality monitoring programs and when considering setting water quality objectives for a drainage.

1 INTRODUCTION

Consolidated Cinola Mines Ltd., (Cinola) have proposed to develop an open pit gold mine located 18 kilometers south of Port Clements on Graham Island (Queen Charlotte Islands) B.C. The mine site is located in the Yakoun River drainage (Figure 1). As part of the procedure for obtaining Provincial approval (1) to develop the minesite, Cinola submitted a Stage I report (2) which included a description of the existing environmental and social conditions of the area, a conceptual design of the proposed mine, environmental and social impacts and proposed further studies. Cinola were further required to submit a Stage II report that must contain a description of the final project design including a description of the project and options considered, an environmental and social impact assessment and how any impacts are to be managed. The Stage II program is presently in progress.

The Cinola project was identified as having a potential for impacting upon the anadromous fishery and migratory bird resources of the area. Thus, the overall project fell within the mandates of the Federal Department of Environment and Department of Fisheries and Oceans for review. This review takes the form of assessing the overall project design and includes the review of impact assessments such as those in the Stage I report and those to be included in the Stage II report.

The Stage I report described the mine operation as having a potential production rate of 9070 tonne of ore/day. A 45 tonne/day pilot mill was operated in 1981 to assess what the final mining method would be and this would be the basis for the Stage II assessment. The Stage I report summarized that the ore, waste rock, soils and tailings may contain anomalously high levels of mercury and other heavy metals. In addition, it was summarized that the proximity of the mine to valuable anadromous and resident fishery resources in the Yakoun River drainage would necessitate extreme vigilance in the design of containment and treatment facilities. Maintance of high quality surface and groundwater runoff into the drainage

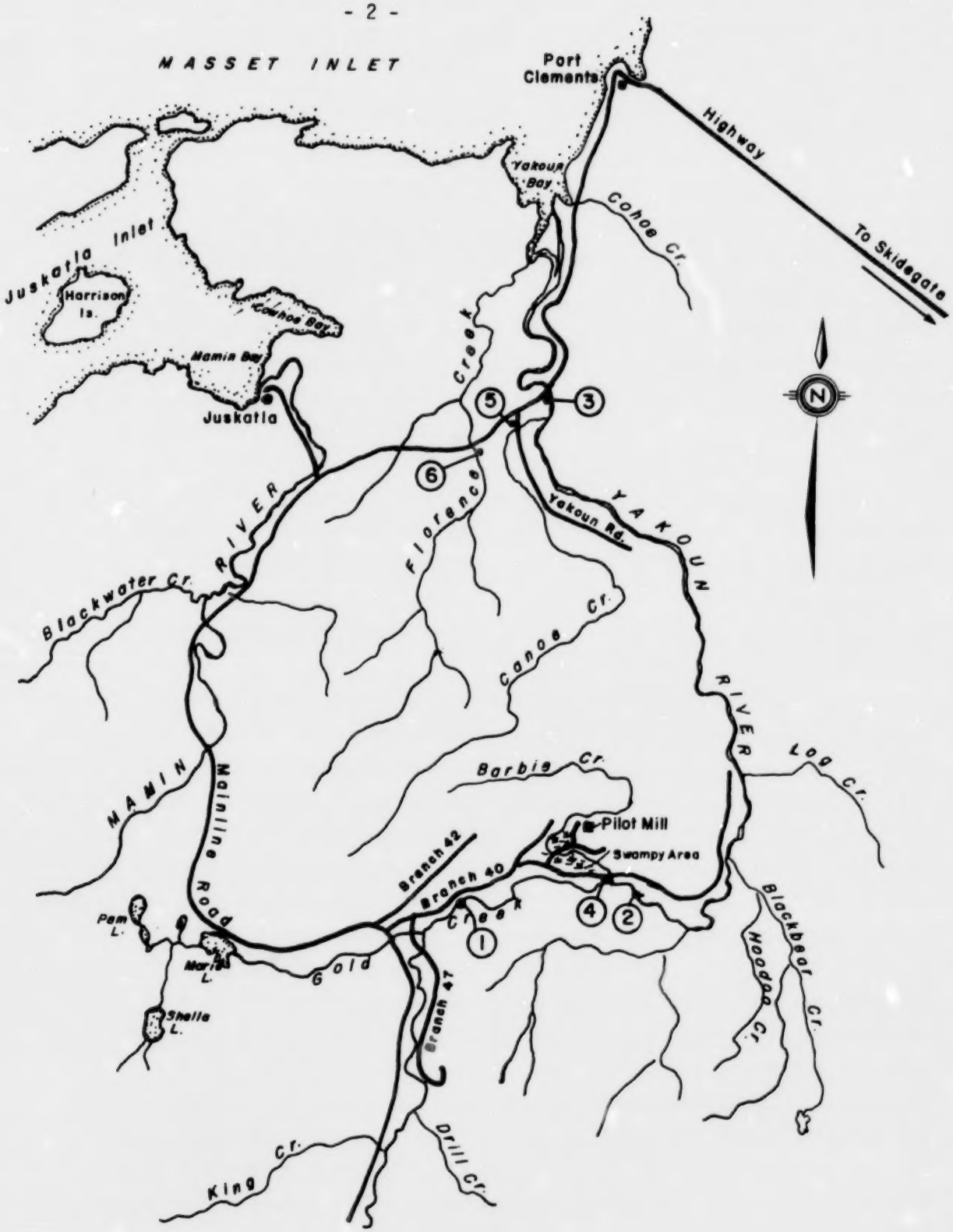


FIGURE 1 YAKOUN RIVER AND SAMPLE STATION LOCATIONS

was reported as essential to ensure adequate protection for the Yakoun River fishery. As part of the overall Stage II environmental program to collect pre-development base line data, the consultant acting on behalf of Cinola, conducted a water quality monitoring program (for analysis of heavy metals and other physical tests) and a stream sediment collection program (for analysis of heavy metals).

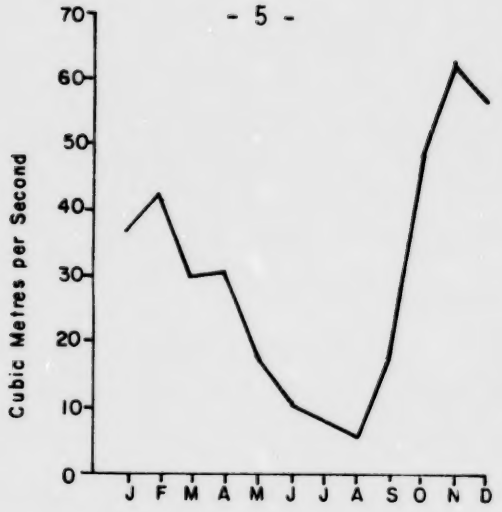
In order to further document the background water quality of the Yakoun River drainage and assess the variability of the water quality (temporal, spatial), the Environmental Protection Service (Department of Environment) undertook a monitoring program in 1981. All samples were analyzed for background heavy metal levels. This report presents the data collected during the June 1981, September 1981 and March 1982 surveys.

2 DESCRIPTION OF STUDY AREA

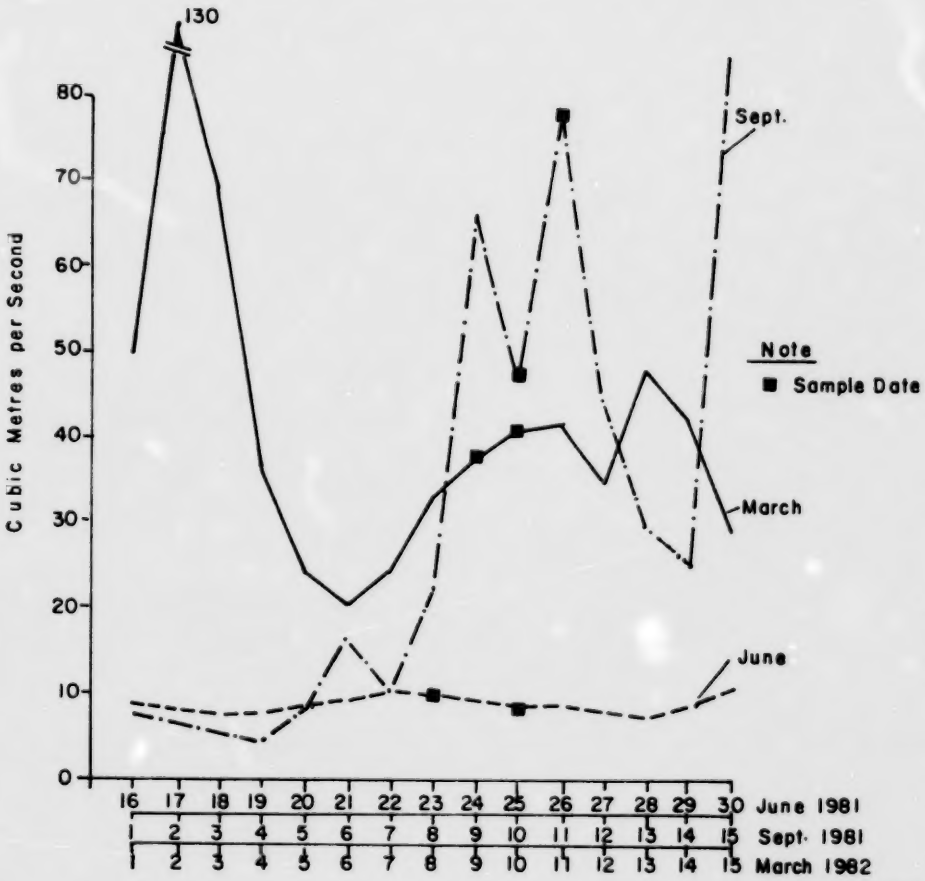
The Yakoun River drains an area of approximately 477 km^2. The Yakoun River flows in a northerly direction and drains into Masset Inlet near Port Clements (Figure 1). Major tributary streams of the Yakoun River that have been identified as having a possibility of being influenced by the Cinola project include Canoe Creek, Florence Creek and Barbie Creek (Figure 1).

As a tailing disposal area had not as yet been decided upon, it was decided not to concentrate stations in any one area but to get a broader overall evaluation of the area. Thus, six water quality sample stations were established within the Yakoun River drainage to obtain background data. The sample stations are described in Table 1 and are shown in Figure 1.

The Yakoun River flows for the three periods of sampling are shown in Figure 2 and have been compiled from Water Survey of Canada flow records (3, 4, 5).



AVERAGE MONTHLY MEAN FLOW - 1975 to 1981



DAILY FLOWS FOR JUNE, SEPTEMBER 1981 AND MARCH 1982

FIGURE 2 YAKOUN RIVER FLOWS (WSC 080A002), 1981- 1982

TABLE 1: DESCRIPTION OF SAMPLE STATIONS ON THE YAKOUN RIVER AND TRIBUTARY STREAMS

RIVER/CREEK	STATION NUMBER*	DESCRIPTION
Yakoun River	1	Located approx. 1.3km downstream of Gold Creek on the north side. Access at a turnoff on Branch 40. The turnoff is located 1.2km west of the Branch 40/ Branch 49 junction.
Yakoun River	2	Located approx. 0.6km downstream of Barbie Creek on the north side. Access at turn-off on Branch 40. The turnoff is located 0.5km west of where Barbie Creek flows under Branch 40.
Yakoun River	3	Located approximately 40m upstream of Main Line road bridge over lower Yakoun River. On west side downstream of logs chained across the river.
Barbie Creek	4	Located half-way between Branch 40 road and the Yakoun River.
Canoe Creek	5	Located on upstream side of Yakoun logging road bridge crossing lower Canoe Creek.
Florence Creek	6	Located on upstream side of Main Line road bridge crossing Florence Creek.

*(See Figure 1)

3 MATERIALS AND METHODS

3.1 Water Samples

3.1.1 Inorganics (excluding metals), Temperature and Flow

A single grab sample was collected on each sample date. The samples were collected in a 2.5 litre polyethylene sample bottle submerged below the water surface (15cm where possible). Each sample was stored in a refrigerator or in a cooler until analyzed at the Cypress Creek laboratory. The samples were analyzed for pH, alkalinity, conductivity, tristimulus colour, total organic carbon, total residue, non-filterable residue, total volatile residue and volatile non-filterable residue. The analytical methods used are those outlined in the Cypress Creek Laboratory Manual (6).

An additional (200ml) sample was collected for pH analysis using a field pH meter and a Hach pH Kit. Temperature was determined with a pocket-thermometer and flows are those provided courtesy of IEC Consultants.

3.1.2 Total and Dissolved Metals and Hardness

In order to assess the spatial variability of heavy metal levels in the water, 3 replicate samples were collected simultaneously. All three bottles (200 ml acid-washed polyethylene) were contained in a larger polyethylene sample bottle modified to hold them in place. After being rinsed with the water being sampled, the bottles were submerged, where possible, to a depth of 15cm and allowed to fill. Samples were collected on two seperate days during each of the surveys to try to assess if any changes occurred in water quality over a 1 to 2 day period. It was hoped that the influence of a major storm event (i.e. increased rainfall) could be assessed to determine if any change in quality could be detected due to an increase in surface run-off.

All analyses were performed at the Department of Environment - Department of Fisheries and Oceans, Cypress Creek laboratory in West Vancouver. The analytical methods used are those outlined in the laboratory Manual of the Cypress Creek laboratory (6). A summary of sample preservation and treatment methods are reported in Table 2. Hardness was computed automatically from the Ca and Mg component of each dissolved metal sample.

TABLE 2: PRESERVATION AND TREATMENT OF WATER SAMPLES FOR HEAVY METAL ANALYSES

	WATER SAMPLES			
PARAMETER	PRESERVATION	PREPARATION-DECOMPOSITION	SEPARATION-CONCENTRATION	ANALYSIS
Total Mercury	10mls of nitric-dichromate acid per 200 ml sample (211)	H_2SO_4, HNO_3, $K_2S_2O_8$ (224)	volatilization (284)	Flameless Atomic Absorption (411)
Total Arsenic & Selenium	add nitric acid to sample to pH L1.5 (210)	12ml aqua regia per 100 ml, heat (220)	(284)	Inductively Coupled Argon Plasma (ICAP) Atomic Emission Spectrophotometry (592)*
Dissolved Arsenic & Selenium	sample field filtered with 0.45u cellulose nitrate membrane filter and add nitric acid to sample to pH L1.5 (203)	-	(284)	(592)*
Total Metals	(210)	(220)	-	(592)
Dissolved Metals	(203)	-	-	(592)

* hydride method (for As, determines uncomplexed As only).

(211) refers to code in Cypress Creek Laboratory Manual

L = less than

4 OBJECTIVES AND CRITERIA FOR THE PROTECTION OF FRESHWATER AQUATIC LIFE

For evaluation purposes, the concentrations of specific metals have been compared to recommended Environment Canada objectives (34) and U.S. Environmental Protection Agency (EPA) criterion (21) for the protection of freshwater aquatic life. The reader should consider the rational for the development and use of objectives or criterion.

An objective is a designated concentration of a consituent that when not exceeded, will protect an organism, a community of organisms, a prescribed water use, or a designated multiple-purpose water use with an adequate degree of safety (34). Objectives represent scientific judgments based upon the best available information relevant to Canadian surface waters on the relationships between toxic substances and water use and on the concentration-effect relationships between toxic substances and biological or environmental receptors (34). They should not be used as absolute values for water quality but with considered judgement and with an understanding of their development. The judgement in their use should include a thorough knowledge of the natural quality of the water under consideration, the kinds of organisms it contains and the local hydrological conditions. The Environment Canada objectives are based on a total metal concentration for the following reasons: (1) adequate toxicity data are not available for most chemical species; (2) toxicities of many metal constituents in water correlate well with the "free ion" concentration but methods for measuring "free ion" concentrations routinely are presently not available; (3) many constituents enter the water system adsorbed on, or absorbed in, particulate matter and are subsequently released to the water by chemical, physical and microbial action and (4) at the present time there is insufficient information available to allow the determination of the fraction of toxicants present in the suspended matter which is biologically available, thus "total" will represent a maximum limit for the biologically available material (34).

Criteria are not rules and they have no regulatory impact but represent scientific data and guidance on the environmental effect of pollutants which can be useful to derive regulatory requirements based on considerations of water quality impact (21). Criteria should be adequate to protect the types of organisms necessary to support an aquatic community but are not designed to protect all life stages of all species under all conditions (21). EPA (21) criteria are based on total recoverable metal because forms of metal that are not measured in the total recoverable procedures are probably not and will not become toxic. The total recoverable procedure has an acid digestion step but it is not as vigorous a digestion as that used in the total metals procedure (35).

5 RESULTS AND DISCUSSION

5.1 Water Samples

The analytical results from this study represent the water quality of the Yakoun River, Barbie Creek, Canoe Creek and Florence Creek for the period June 23 and 25, 1981, September 10 and 11, 1981 and March 9 and 10, 1982.

5.1.1 Inorganics (excluding metals), Temperature and Flow. The parameters in this section generally deal with the standard tests used to describe water.

5.1.1.1 Total Alkalinity (as $CaCO_3$) Total Acidity (as $CaCO_3$), pH and Hardness (as $CaCO_3$). Whereas alkalinity and acidity are measures of the total resistance to pH change or buffering capacity of a sample, pH represents the free hydrogen ion activity not bound by carbonate or other bases (8).

Total Alkalinity

The alkalinity of a water is its quantitative capacity to react with a strong acid to a designated endpoint pH (i.e. 4.5) (14). Because the alkalinity of many surface waters is primarily a function of carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) and hydroxide (OH^-) content, the alkalinity is taken as an indication of the concentration of these constituents (14). The measured values may include contributions from phosphates, silicates or borates if these are present. A few organic acids, for example, humic acids, form salts that add to the alkalinity of natural waters (6). Less than 20 mg/l (as $CaCO_3$) is considered to be of low alkalinity.

The alkalinity of the streams measured was always less than 20 mg/l and the range for each stream (in descending order by stream) over the three surveys is: Yakoun River (15.1-6.0 mg/l); Florence Creek (8.8-2.0 mg/l), Barbie Creek (7.8-1.5 mg/l) and Canoe Creek (5.5-0.5 mg/l)

(Table 3). The Yakoun River and the tributary streams monitored would have very little quantitative capacity to buffer an acidic discharge. The alkalinity of a system not only influences the suitability of the system for biological activity, it influences the composition of the biological community as well (9).

Total Acidity

The acidity of a water is its quantitative capacity to react with a strong base to a designated endpoint pH (i.e. 8.3) (14). Strong mineral acids, weak acids such as carbonic (H_2CO_3) and acetic, and hydrolyzing salts such as ferrous or aluminum sulfates may contribute to the measured acidity according to the method of determination (14). Acidity in surface or groundwaters may be attributed to natural causes such as humic acids extracted from swamps or peat bogs (15).

Acidity was measured only in March 1982 and levels didn't exceed 8.0 mg/l (Table 3). The stream with the lower alkalinity had the higher acidity.

pH

The pH of a water refers to its hydrogen ion (H^+) activity. The principal system regulating pH in natural waters if the carbonate system which is composed of carbon dioxide (CO_2 gas), carbonic acid (H_2CO_3) and hydrated carbon dioxide ($CO_2 \cdot H_2O$), bicarbonate ion (HCO_3^-) and carbonate ion (CO_3^{2-}) (9).

The pH of the streams measured did not exceed 7.1 and the range for each stream (in descending order by steam) over the three surveys is: Yakoun River (7.1 - 6.6); Florence Creek (6.4 - 5.7); Barbie Creek (6.3 - 5.3) and Canoe Creek (6.0 - 5.1) (Table 3). This is the same order as was observed for alkalinity.

Thurston et al (9) reported that based on present evidence, a pH range of 6.0 to 9.0 appears to provide complete protection for the life of freshwater fish species and the bottom-dwelling invertebrate fish food

Table 3 TOTAL ALKALINITY, TOTAL ACIDITY, pH AND HARDNESS OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS

PARAMETER	1981				1982	
	June 23	June 25	September 10	September 11	March 9	March 10
Alkalinity (mg/l)						
Yakoun R #1	13.3	13.8	9.4	8.3	8.0	7.5
Yakoun R #2	14.3	15.1	9.5	8.3	8.0	7.0
Yakoun R #3	13.3	13.3	8.9	9.8	6.0	6.0
Barbie Cr	7.8	6.9	3.4	4.2	1.5	2.0
Canoe Cr	5.1	5.5	2.7	2.7	0.5	0.5
Florence Cr	8.8	7.4	4.7	5.3	2.0	2.0
Acidity (mg/l)						
Yakoun R #1	-	-	-	-	3.0	2.5
Yakoun R #2	-	-	-	-	3.0	2.5
Yakoun R #3	-	-	-	-	3.5	4.0
Barbie Cr	-	-	-	-	6.5	6.0
Canoe Cr	-	-	-	-	7.5	8.0
Florence Cr	-	-	-	-	6.0	6.0
pH						
Yakoun R #1	7.1	7.1	6.9	6.7	6.9	6.8
Yakoun R #2	7.1	7.1	6.8	6.8	6.8	6.8
Yakoun R #3	7.0	6.7	6.7	6.8	6.7	6.6
Barbie Cr	6.3	6.2	5.3	5.5	5.6	5.6
Canoe Cr	6.0	5.9	5.1	5.1	5.3	5.3
Florence Cr	6.4	6.3	5.7	5.8	5.8	5.8
Hardness* (mg/l)						
Yakoun R #1	13.4 (.06)	13.4 (.06)	11.4 (.12)	11.9 (.06)	12.3 (.10)	11.6 (.11)
Yakoun R #2	13.6 (.23)	13.8 (.10)	11.7 (.06)	11.9 (.17)	11.8 (.06)	11.8 (.20)
Yakoun R #3	13.6 (.10)	14.0 (.11)	12.5 (.10)	11.5 (.32)	10.9 (.00)	10.9 (.10)
Barbie Cr	10.2 (.22)	10.7 (.11)	14.1 (.10)	13.7 (.12)	9.2 (.15)	8.8 (.06)
Canoe Cr	6.9 (.17)	7.6 (.10)	8.9 (.06)	7.6 (.15)	5.0 (.06)	5.3 (.06)
Florence Cr	9.0 (.07)	9.2 (.07)	10.1 (.20)	9.5 (.20)	5.7 (.06)	5.8 (.06)

*mean and (standard deviation) reported, n = 3

organisms. This is provided the cations and anions whose toxicity is pH-dependent, are absent in concentrations which may be lethal. Outside of this range fish may suffer some slight adverse physiological effects which increase in severity if the deviation is large and persists for long periods of time (9). A suggested criteria for nearly maximum protection was a pH range of 6.5 to 8.5 with no change greater than 0.5 unit outside estimated natural seasonal maximum and minimum (9). A high level of protection was suggested to be a pH range of 6.0 - 9.0 with no change greater than 0.5 unit.

It is worthy to note that for the three tributary streams, the natural pH can be below the lower level of pH 6 suggested as a criteria for a high level of protection.

The hydrogen ion activity in water is extremely important in governing the species and solubility of metals and therefore their lethal toxicity (10). At a high pH, many metals form hydroxides or basic carbonates that are relatively insoluble and tend to precipitate. It is difficult to predict the effect of pH on toxicity (10).

Hardness

Water hardness is a measure of polyvalent metallic ions and in freshwaters these are principally calcium and magnesium although other metals such as aluminum, iron, manganese, strontium and zinc may contribute to total hardness (8). A commonly used classification for soft, moderately hard and hard waters (as $CaCO_3$) is: 0 - 75 mg/l, 75 - 150 mg/l and 150 - 300 mg/l respectively (11).

The mean hardness of the streams measured didn't exceed 14.1 mg/l and would all be considered soft (Table 3). The mean hardness range for each stream (in descending order by stream) over the three surveys is: Yakoun River (14 - 10.9 mg/l); Barbie Creek (14.1 - 8.8 mg/l); Florence Creek (10.1 - 5.7 mg/l) and Canoe Creek (8.9 - 5.0 mg/l).

The important relationship between water hardness and lethal toxicity is well documented for some metals (10) and with more stringent criterion set for softwaters (21).

5.1.1.2 Total, Non-filterable and Total Volatile Residues and Total Organic Carbon.

Residues

Residue measurements are descriptive of the organic and inorganic solid matter in water. Total residue includes non-filterable residue (suspended solids), that is, the proportion of the total residue retained by a filter. Volatile residue refers to that protion of the total residue that is lost by ignition at 550°C and represents a rough approximation of the organic fraction.

Environmental concerns related to solid matter in water are primarily those dealing with direct physical effects on fish and on the deposition of solids within the river substrate.

For the streams monitored as a whole, the total residue levels ranged between 52 to 130 mg/l, non-filterable residue between less than 5 to 63 mg/l and total volatile residue between less than 5 to 71 mg/l (Table 4).

The low levels of non-filterable residue (generally < 5 mg/l) respective to total residue indicate residue levels are mainly of a filterable (< 1.2 um) size range i.e. effective retention of Whatman GFC filter. The high total volatile residue levels reflect the organic nature of the Yakoun River and tributary streams. The influence of a major storm event (rainfall and associated surface runoff, Figure 2) can be seen between September 10 and 11, 1981 with respect to an increase in all residue fractions for the Yakoun River stations. There was no evident increase in residue levels in Barbie Creek, Canoe Creek or Florence Creek. It is interesting to note the higher residue levels at Yakoun R#3 relative to Yakoun R#1 and #2 for the September sample dates.

EPA (10), citing the work of others, reported that aquatic communities should have high and moderate levels of protection if the maximum concentrations of suspended solids that exist are 25 mg/l and 80 mg/l, respectively. Non-filterable (suspended) solid levels for the Yakoun drainage with the exception of one sample were all less than 25 mg/l.

Table 4 TOTAL, NON FILTERABLE AND TOTAL VOLATILE RESIDUES AND TOTAL ORGANIC CARBON OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS

PARAMETER	1981				1982	
	June 23	June 25	September 10	September 11	March 9	March 10
Total Residue (mg/l)						
Yakoun R #1	52	55	54	79	53	64
Yakoun R #2	60	60	53	82	53	54
Yakoun R #3	68	80	76	130	58	56
Barbie Cr	104	106	102	105	63	59
Canoe Cr	90	97	108	105	70	66
Florence Cr	95	95	106	110	67	74
Non-Filterable Residue (mg/l)						
Yakoun R #1	L5	L5	L5	16	L5	9
Yakoun R #2	L5	L5	L5	21	L5	7
Yakoun R #3	5	L5	11	63	6	L5
Barbie Cr	9	14	L5	L5	L5	L5
Canoe Cr	L5	L5	L5	L5	L5	L5
Florence Cr	L5	L5	L5	L5	L5	L5
Total Volatile Residue (mg/l)						
Yakoun R #1	5	6	20	33	19	21
Yakoun R #2	L5	8	21	31	20	18
Yakoun R #3	13	19	33	40	24	25
Barbie Cr	36	38	52	56	33	31
Canoe Cr	44	45	71	60	40	33
Florence Cr	41	48	67	65	38	39
Total Organic Carbon (mg/l)						
Yakoun R #1	9	6	10	14	7	7
Yakoun R #2	6	6	9	13	7	8
Yakoun R #3	8	11	13	17	8	10
Barbie Cr	20	25	23	22	12	13
Canoe Cr	24	-	31	27	18	19
Florence Cr	24	-	28	27	18	18

Total Organic Carbon

The organic nature of the Yakoun River drainage is indicated in the total organic carbon (TOC) measurement (Table 4). The three tributary streams had higher TOC concentrations than the mainstem Yakoun River. The range for each stream (in descending order by stream) over the three surveys is: Canoe Creek (18-31 mg/l); Florence Creek (18-28 mg/l); Barbie Creek (12-25 mg/l) and Yakoun River (6-17 mg/l).

Natural sources contribute to the bulk of the organic matter present in most surface waters and humic and fulvic acids constitute the majority of the organic matter (12). Humic substances are dark coloured, acidic, predominantly aromatic, hydrophilic, chemically complex polyelectrolytes that range in molecular weights (13). Quantitative measurements of humic and fulvic acids were not made during the course of this study.

The affinity of heavy metals for organic substances and for their decomposition products is of great importance in the behavior of trace substances in aquatic systems (36). The order of bonding strength for a number of metal ions onto humic and fulvic acids has been reported as $Hg^{2+} > Cu^{2+} > Pb^{2+} > Zn^{2+} > Co^{2+}$ (36).

5.1.1.3 Conductivity, Tristimulus Colour, Temperature and Flow.

Conductivity

Conductivity is a numerical expression of the ability of a water sample to carry an electric current and this ability depends on the presence of ions, their total concentration, mobility, valence and relative concentrations and on the temperature of measurement (14). Solutions of inorganic salts are relatively good conductors whereas molecules of organic compounds that do not dissociate in aqueous solution conduct a current very poorly (14). Freshly distilled water has a conductivity of 0.5-2.0 umhos/cm and the conductivity of potable waters in the United States generally ranges between 50 to 1500 umhos/cm (14). Inland freshwaters supporting a good mixed fish fauna lay, in general, between 150-500 umhos/cm (15).

Conductivity measurements for the Yakoun drainage were within a range of 35.2 to 67.5 umhos/cm (Table 5).

Tristimulus Colour

Colour in water principally results from the degradation processes in the natural environment and the most common causes are complex organic compounds originating from the decomposition of naturally-occurring organic matter (11). The range of colour for each stream (in descending order by stream) over the three surveys is: Canoe Creek (165 - 322); Florence Creek (149 - 319); Barbie Creek (90 - 305) and the Yakoun River (50 - 122) (Table 5). These high colour values reflect the naturally brown colouration of streams in the Yakoun drainage. A biologically treated kraft pulpmill effluent diluted with distilled water to a concentration of 10% and 20% gave a tristimulus colour 184 and 403 respectively (EPS, unpublished data).

Temperature and Flow

Stream temperatures ranged between 1°C to 14°C during the study period (Table 5).

The most significant change in stream flows was noted between September 10 and 11, 1982 during a period of heavy rainfall and flows in some cases doubled over 24 hrs (Table 5).

5.1.2 Total and Dissolved Metals. When evaluating the results herein, consideration should be given to the conventional but arbitrary method of distinguishing total from dissolved. Total metals includes all metals (after a strong acid digestion pretreatment) inorganically and organically bound, and both dissolved and particulate. Dissolved metals includes all metals (without strong acid digestion pretreatment) inorganically and organically bound but the sample has been previously filtered through a 0.45 um membrane filter (6).

Table 5 CONDUCTIVITY, TRISTIMULUS COLOUR, TEMPERATURE AND FLOW OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS

PARAMETER	1981				1982	
	June 23	June 25	September 10	September 11	March 9	March 10
Conductivity (umhos/cm)						
Yakoun R #1	47.1	47.6	41.1	41.9	45.3	44.3
Yakoun R #2	48.1	48.6	41.7	42.5	45.8	44.5
Yakoun R #3	50.0	50.5	44.7	42.5	46.3	45.0
Barbie Cr	49.6	48.4	67.5	66.2	51.7	48.8
Canoe Cr	39.6	40.9	49.0	44.7	39.8	39.2
Florence Cr	41.3	41.1	46.3	45.2	36.0	35.2
Colour						
Yakoun R #1	61	50	71	107	50	59
Yakoun R #2	62	54	73	122	53	62
Yakoun R #3	84	109	117	105	75	73
Barbie Cr	272	305	199	206	90	101
Canoe Cr	308	322	265	242	173	165
Florence Cr	270	319	262	251	153	149
Temperature (°C)						
Yakoun R #1	13	12	12.5	12.5	2.2	2
Yakoun R #2	12	13	14	12	2.2	2
Yakoun R #3	12	12	13.5	12.5	2.2	2.2
Barbie Cr	13	14	13.5	12	3.2	3
Canoe Cr	10	10	12	11	1.2	1.2
Florence Cr	10.5	10	12.5	11.5	1	1
Flow* (m^3/s)						
Yakoun R #1	-	-	-	-	-	-
Yakoun R #2	-	-	-	-	-	-
Yakoun R #3	9.99	8.28	47.2	77.6	37.8	41.0
Barbie Cr	.72	.67	1.0	1.52	.89	.85
Canoe Cr	.78	.73	1.35	2.45	1.77	1.84
Florence Cr	.25	.25	1.0	2.4	2.50	2.85

*Yakoun R #3 from WSC station 08OA002 and creek flows supplied courtesy of IEC Consultants.

The less than 0.45 um fraction can include: finely divided suspended matter (in general suspended particles are considered to be greater than 0.1 um); soluble particles (less than .001 um) and colloidal particles (greater than .001 um but less than 0.1 um) (6). The suspended and colloidal particles may consist of individual or mixed metals in the form of their hydroxides, oxides, silicates, sulfides or as other compounds. They may also consist of clay, silica or organic matter to which metals are bound by adsorption, ion exchange or complexation. The soluble metals maybe ions, simple or complex, or, un-ionized organometallic chelates or complexes (6).

No attempt was made to further evaluate the form of the dissolved fraction. In order to assess the physiochemical speciation of trace metals, more complicated procedures are necessary (12, 16, 17, 18). It is also important to consider the influence of filtration in distinguishing between dissolved and particulate fractions (19).

In this report the term extractable metal has somethimes been referred to. Extractable denotes that the sample has neither been filtered (as in dissolved) nor received a strong acid digestion (as in total).

5.1.2.1 Total Mercury and Total and Dissolved Arsenic.

Mercury

In general, the total mercury levels were below the detection limit of 0.2 ug/l (Table 6, Appendix 1). The higher mean value for Yakoun R#1 on September 11, 1981 is due to a single high value of 0.7 ug/l (Appendix I). The influence of the increased surface runoff due to rainfall between September 10 and 11, 1981 didn't appear to have a strong influence on total mercury levels at the 0.2 ug/l detection level, however, the low but detectable levels of total mercury in a few replicates might suggest some influence due to an increased river discharge during the period immediately prior to and during sampling (Figure 2).

High concentrations of mercury are rarely found in natural waters due to its low solubility, high affinity for organic matter and volatility (20). Mercury rapidly adsorbs onto suspended particulate

Table 6 MERCURY AND ARSENIC LEVELS OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS

METAL**	1981								1982			
	June 23		June 25		September 10		September 11		March 9		March 10	
	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)
Total Hg												
Yakoun R #1	L0.2	(0.0)	L0.2	(0.0)	L0.2	(0.0)	.37	(.29)	L0.2	(0.0)	L0.2	(0.0)
Yakoun R #2	L0.2	(0.0)	L0.2	(0.0)	L0.2	(0.0)	.23	(.06)	L0.2	(0.0)	L0.2	(0.0)
Yakoun R #3	L0.2	(0.0)	L0.2	(0.0)	0.23	(.06)	L0.2	(0.0)	L0.2	(0.0)	L0.2	(0.0)
Barbie Cr	L0.2	(0.0)	L0.2	(0.0)	L0.2	(0.0)	L0.2	(0.0)	L0.2	(0.0)	L0.2	(0.0)
Canoe Cr	L0.2	(0.0)	L0.2	(0.0)	0.21	(.02)	L0.2	(0.0)	L0.2	(0.0)	L0.2	(0.0)
Florence Cr	L0.2	(0.0)	L0.2	(0.0)	L0.2	(0.0)	L0.2	(0.0)	L0.2	(0.0)	L0.2	(0.0)
Diss. As												
Yakoun R #1	-		-		L0.5	(0.0)	L0.5	(0.0)	L0.5	(0.0)	L0.5	(0.0)
Yakoun R #2	-		-		L0.5	(0.0)	L0.5	(0.0)	L0.5	(0.0)	L0.5	(0.0)
Yakoun R #3	-		-		L0.5	(0.0)	L0.5	(0.0)	L0.5	(0.0)	0.7	(.35)
Barbie Cr	-		-		1.1	(.06)	1.1	(0.0)	L0.5	(0.0)	L0.5	(0.0)
Canoe Cr	-		-		L0.5	(0.0)	L0.5	(0.0)	L0.5	(0.0)	L0.5	(0.0)
Florence Cr	-		-		L0.5	(0.0)	L0.5	(0.0)	L0.5	(0.0)	L0.5	(0.0)
Total As												
Yakoun R #1					0.5	(.06)	0.6	(0.1)	0.7	(.29)	L0.5	(0.0)
Yakoun R #2					L0.5	(0.0)	0.7	(0.0)	L0.5	(0.0)	L0.5	(0.0)
Yakoun R #3					L0.5	(0.0)	1.7	(0.1)	L0.5	(0.0)	L0.5	(0.0)
Barbie Cr					2.0	(.26)	2.0	(0.0)	L0.5	(0.0)	0.5	(.06)
Canoe Cr					0.6	(.06)	0.7	(.21)	0.6	(.23)	L0.5	(0.0)
Florence Cr					L0.5	(0.0)	L0.5	(0.0)	0.7	(.40)	L0.5	(0.0)

**as ug/l (ppb), n = 3, detection limit used in mean calculation, see Appendix I for tabulated data.

matter in the water column and is ultimately deposited in the bottom sediments and therefore, the concentration of mercury in surface waters is largely dependent upon the amount of suspended particulate matter in the water column (20). Garrett et al (20) recognized 0.2 ug/l as a criteria level indicating some degree of mercury contamination in natural waters and this is based on the fact that it is the routine detection limit of many laboratories.

EPA (21, 22) in their re-evaluation of mercury criteria set a total recoverable mercury criteria to protect freshwater aquatic life of 0.2 ug/l as a 24-hour average and the concentration should not exceed 4.1 ug/l at any time.

For the protecion of aquatic life Environment Canada recommended the water quality objective for mercury to not exceed 0.2 ug/l total mercury (23). It was also recommended that a level of 0.1 ug/l total mercury be the objective in waters where fish play an important role in the economy of the area (23). Guidelines for Canadian drinking water quality recommend a maximum acceptable total mercury concentrations of 1.0 ug/l and an objective concentration of less than or equal to 0.2 ug/l (24).

Arsenic

Arsenic levels were measured in September 1981 and March 1982. Arsenic levels were low and ranged from less than 0.5 ug/l to 2.3 ug/l as total arsenic (Appendix I). The influence of increased surface runoff during the September sampling period can be seen in the total arsenic levels (Table 6). The Yakoun River stations showed small but detectable changes between the September 10 and September 11 sample dates and with Florence Creek not showing any increase above the detection limit. The detectable levels of total arsenic in Barbie Creek on September 10 ($\bar{x}$ = 2 ug/l) might indicate levels were already elevated due to increased surface runoff prior to the sampling period (as reflected in Yakoun River hydrograph, (Figure 2). For the Yakoun River stations #1 and #2, total

mean arsenic levels increased from the detection limit of 0.5 ug/l to just detectable (0.6 - 0.7 ug/l). However, Yakoun R#3 levels increased from below 0.5 ug/l to a mean value of 1.7 ug/l (Table 6). It should be noted again that the largest increase in total residue and non-filterable residue occurred on the Yakoun River between September 10 and September 11 indicating an association between the suspended solids and total arsenic.

With the exception of Barbie Creek in September, dissolved arsenic levels were below 0.5 ug/l and again indicating arsenic was associated with a particulate form (greater than 0.45 um). Mean dissolved arsenic levels for Barbie Creek were 1.1 ug/l on the September sample dates compared to a mean total arsenic concentration of 2.0 ug/l (Table 6). Total arsenic levels were generally below 0.5 ug/l in March although a few samples showed detectable levels (Appendix I).

Demayo et al (25) reported that the dissolved arsenic concentration in over 5400 river water samples collected over 1972-1977 ranged from less than 1 ug/l to approximately 50 ug/l, with 90% of the results being below 8 ug/l.

For the protection of aquatic life Environment Canada recommended the water quality objective for total arsenic to be 50 ug/l (25). Guidelines for Canadian drinking water quality recommend a maximum acceptable total arsenic concentration of 50 ug/l and an objective concentration of less than or equal to 5 ug/l (24).

5.1.2.2 Total and Dissolved Lead and Zinc.

Lead

Mean total and dissolved lead concentrations never exceeded the detection limit of 40 ug/l in June and September, 1981 (Table 7). A change in the detection limit calculation between September 1981 and March 1982 resulted in a lower detection limit of 20 ug/l for the last survey. Unfortunately, the earlier survey results could not be recalculated using the revised detection limit. For consistency the March, 1982 values on

Table 7 LEAD AND ZINC LEVELS OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS

METAL**	1981								1982			
	June 23		June 25		September 10		September 11		March 9		March 10	
	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)
Diss. Pb												
Yakoun R #1	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Yakoun R #2	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Yakoun R #3	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Barbie Cr	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Canoe Cr	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Florence Cr	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Total Pb												
Yakoun R #1	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Yakoun R #2	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Yakoun R #3	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Barbie Cr	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Canoe Cr	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Florence Cr	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Diss. Zn												
Yakoun R #1	L5	(0.0)	L5	(0.0)	L5	(0.0)	7	(.6)	11	(9.8)	L5	(0.0)
Yakoun R #2	L5	(0.0)	L5	(0.0)	L5	(0.0)	6	(.6)	L5	(0.0)	L5	(0.0)
Yakoun R #3	L5	(0.0)	L5	(0.0)	L5	(0.0)	6	(.6)	L5	(0.0)	L5	(0.0)
Barbie Cr	L5	(0.0)	L5	(0.0)	13	(0.6)	18	(1.7)	6	(1.1)	6	(1.1)
Canoe Cr	L5	(0.0)	L5	(0.0)	L5	(0.0)	7	(1.1)	L5	(0.0)	L5	(0.0)
Florence Cr	L5	(0.0)	L5	(0.0)	L5	(0.0)	7	(1.0)	L5	(0.0)	L5	(0.0)
Total Zn												
Yakoun R #1	L5	(0.0)	L5	(0.0)	7	(2.9)	20	(.6)	L5	(0.0)	5	(.6)
Yakoun R #2	6	(1.7)	5	(.6)	6	(1.1)	87	(51.9)	L5	(0.0)	L5	(0.0)
Yakoun R #3	6	(1.0)	7	(4.0)	5	(.6)	187	(200)	L5	(0.0)	L5	(0.0)
Barbie Cr	6	(.6)	L5	(0.0)	68	(40.5)	90	(58.1)	9	(1.0)	8	(1.1)
Canoe Cr	L5	(0.0)	7	(4.0)	7	(3.5)	113	(159.1)	L5	(0.0)	6	(2.3)
Florence Cr	L5	(0.0)	13	(13.3)	L5	(0.0)	101	(89.9)	L5	(0.0)	L5	(0.0)

**as ug/l (ppb), n =3, detection limit used in mean calculation, see Appendix I for tabulated data.

L = less than

L = values less than or equal to the detection limit reported.

Table 7 have been reported at the higher detection, but the lower detection limit results are reported in Appendix I.

Total lead concentrations between 20 - 40 ug/l were detected in the study area in March 1982 (Appendix I). However, the dissolved lead concentrations were all below 20 ug/l indicating some lead associated with the particulate fraction greater than 0.45 um (Appendix I).

Due to the high detection limit for lead in the ICAP analysis it is difficult to relate the values recorded to water quality objectives. All concentrations were below the maximum acceptable concentration of 50 ug/l for Canadian drinking water quality (24). Environment Canada (26) recommended a total lead objective of 5 ug/l in soft water (hardness < 95 mg/l as $CaCO_3$) for the protection of aquatic life and 10 ug/l in water with a hardness greater than 95 mg/l as $CaCO_3$. EPA (21) reported a total recoverable lead criterion based on hardness and as example for a hardness of 50, 100 and 200 mg/l (as $CaCO_3$) the concentrations should not exceed 74, 170 and 400 ug/l respectively at any time. The total lead concentrations in March 1982 of between 20 - 40 ug/l indicate the recommended Environment Canada criterion for total lead are exceeded.

Zinc

As with lead, a change in the determination of the detection limit resulted in a lower detection level of 2 ug/l in March 1982. For consistency the March 1982 levels are reported at the higher detection level in Table 7 but the lower detection results are reported in Appendix I for March 1982.

Mean total and dissolved zinc concentrations were generally at or near the 5 ug/l detection limit, except in September when elevated concentrations ocurred probably as a result of increased surface runoff (Table 7). In September, the elevations in total and dissolved zinc were evident at all stations (Appendix I). The difference between the total and dissolved zinc fraction indicated the zinc was mainly in a particulate fraction greater than 0.45 um. The high standard deviation for total zinc

indicates there is a very large spread for the individual measurements among the three replicates (Table 7, Appendix 1). Barbie Creek had the highest dissolved zinc levels with a mean of 13 ug/l and 18 ug/l on September 10 and 11 respectively. The higher mean concentration for dissolved zinc at Yakoun R#1 on March 9, 1982 (Table 7) is a result of a high single value of 22 ug/l (Appendix 1). Outliers of this nature may be related to field technique, contamination or analytical error (7).

Taylor and Demayo (27) reported that the extractable zinc concentrations in approximately 12000 samples of river water collected in Canada between 1972 and 1977 ranged from less than 1 ug/l to approximately 3000 ug/l. Ninety percent of the results were less than 60 ug/l (27). In natural waters zinc probably exists as the simple hydrated ion, inorganic compounds, stable organic complexes and adsorbed onto or occluded in inorganic or organic colloids (27).

For the protection of aquatic life Environment Canada recommended water quality objectives for total zinc based on water hardness (as mg/l $CaCO_3$). The recommended levels of total zinc were 50 ug/l, 100 ug/l, 200 ug/l and 300 ug/l for waters with a hardness of 0 - 120, 120 - 180, 180 - 300 and greater than 300 respectively (27). Some of the total zinc concentrations during the September 1981 survey exceeded the lowest recommended objective. EPA (21) set a total recoverable zinc criterion to protect freshwater aquatic life of 47 ug/l as a 24-hour average. Based on water hardness and as examples, the zinc concentration for a water hardness of 50, 100 and 200 mg/l as $CaCO_3$ should not exceed 180 ug/l, 320 ug/l and 570 ug/l respectively at any time. Guidelines for drinking water quality recommended a maximum acceptable total zinc concentration of 5 mg/l based on aesthetic considerations (24).

5.1.2.3 Total and Dissolved Cadmium and Copper.

Cadmium

A change in the detection limit calculation resulted in a lowering of the limit in the March survey to 2 ug/l compared to 4 ug/l in

June and September. For consistency, the March levels are reported at the higher detection limit in Table 8 but the lower detection results are reported in Appendix I.

Mean total and dissolved cadmium levels didn't exceed the 4 ug/l detection limit and any influence due to increased runoff was not evident over September 10 and 11, 1981 (Table 8). In March 1982, a few replicates had detectable total cadmium concentrations of 2 ug/l and 3 ug/l (Appendix I). Dissolved cadmium concentrations were all less than 2 ug/l in March (Appendix I).

The main form of cadmium is Cd (II), which makes up a series of inorganic and organic compounds. Cadmium carbonate, sulphide and hydroxide have very low solubilities and this is probably why most of the cadmium in the aquatic environment is found in the sediments (28).

For the protection of aquatic life Environment Canada recommended a water quality objective of 0.2 ug/l as total cadmium (28). EPA (21) reported a total recoverable cadmium criterion to protect aquatic life based on hardness and as examples for a hardness of 50, 100 and 200 mg/l as $CaCO_3$ the concentration of total recoverable cadmium should not exceed 1.5 ug/l, 3.0 ug/l and 6.3 ug/l respectively. Both the above objective and lowest criterion are lower than the detection limit reported in this survey. Guidelines for drinking water quality recommend a maximum acceptable total cadmium concentration of 5 ug/l and an objective concentration of less than or equal to 1 ug/l (24).

Copper

The mean total and dissolved copper levels were generally below the detection limit of 5 ug/l (Table 8). Some higher total copper values were detected in June 1981 but the large standard deviation (Table 8) reflects a large spread of individual measurements among the three replicates and in most cases two of the replicates were less than 5 ug/l and one was between 27 and 32 ug/l (Appendix I). These individual high levels were not evident in the dissolved samples. Demayo and Taylor (29)

Table 8 CADMIUM AND COPPER LEVELS OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS

METAL**	1981								1982			
	June 23		June 25		September 10		September 11		March 9		March 10	
	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)
Diss. Cd												
Yakoun R #1	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)
Yakoun R #2	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)
Yakoun R #3	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)
Barbie Cr	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)
Canoe Cr	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)
Florence Cr	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)
Total Cd												
Yakoun R #1	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)
Yakoun R #2	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)
Yakoun R #3	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)
Barbie Cr	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)
Canoe Cr	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)
Florence Cr	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)	L4	(0.0)
Diss. Cu												
Yakoun R #1	L5	(0.0)	L5	(0.0)	L5	(0.0)	L5	(0.0)	5	(0.6)	L5	(0.0)
Yakoun R #2	L5	(0.0)	L5	(0.0)	L5	(0.0)	L5	(0.0)	L5	(0.0)	L5	(0.0)
Yakoun R #3	L5	(0.0)	L5	(0.0)	8	(3.0)	L5	(0.0)	L5	(0.0)	L5	(0.0)
Barbie Cr	L5	(0.0)	L5	(0.0)	L5	(0.0)	L5	(0.0)	L5	(0.0)	L5	(0.0)
Canoe Cr	L5	(0.0)	L5	(0.0)	L5	(0.0)	L5	(0.0)	L5	(0.0)	L5	(0.0)
Florence Cr	L5	(0.0)	L5	(0.0)	L5	(0.0)	L5	(0.0)	L5	(0.0)	L5	(0.0)
Total Cu												
Yakoun R #1	L5	(0.0)	L5	(0.0)	L5	(0.0)	L5	(0.0)	5	(.6)	5	(.6)
Yakoun R #2	L5	(0.0)	12	(12.7)	L5	(0.0)	L5	(0.0)	5	(.6)	L5	(0.0)
Yakoun R #3	L5	(0.0)	5	(.6)	L5	(0.0)	L5	(0.0)	L5	(0.0)	6	(1.1)
Barbie Cr	14	(15.6)	6	(2.3)	L5	(0.0)	L5	(0.0)	5	(.6)	6	(1.5)
Canoe Cr	L5	(0.0)	14	(15.6)	L5	(0.0)	L5	(0.0)	L5	(0.0)	6	(1.0)
Florence Cr	5	(0.6)	13	(13.9)	L5	(0.0)	L5	(0.0)	6	(1.0)	6	(1.7)

**as ug/l (ppb), n = 3

reported that the extractable copper concentrations from Canadian Rivers between 1972 and 1977 ranged from 1 ug/l to approximately 500 ug/l and with 90% of the over 12000 results being below the value of 11 ug/l.

In the aquatic environment copper may be present in solution (cupric ion or complexed), suspended sediments (as precipitates or sorbed on other particles) and bottom sediments (as precipitates or sorbed on other bottom materials) (29).

For the protection of aquatic life Environment Canada recommended a water quality objective of 2 ug/l as total copper (29). EPA (21) reported a total recoverable copper criterion to protect freshwater aquatic life of 5.6 ug/l as a 24 hour average and as examples the concentration based on a hardness of 50, 100 and 200 mg/l as $CaCO_3$ should not exceed 12 ug/l, 22 ug/l and 43 ug/l respectively at any time. A few of the total copper concentrations in this study exceeded the Environment Canada objective and in some cases the lowest EPA criterion. Guidelines for drinking water quality recommended a maximum acceptable total copper concentration of 1 mg/l based on aesthetic considerations (24).

5.1.2.4 Total and Dissolved Chromium and Nickel.

Chromium

A change in the detection limit calculation resulted in a lowering of the limit in the March survey to 5 ug/l compared to 7.5 ug/l in June and September. For consistency, the March levels are reported at the higher detection limit in Table 9 but the lower detection results are reported in Appendix I.

The mean total chromium levels were generally below the detection limit of 7.5 ug/l and all dissolved chromium levels were below the detection limit (Table 9, Appendix I). The single highest total chromium concentration was 36.8 ug/l at Florence Creek on June 23, 1982. Taylor et al (30) reported that the extractable chromium concentrations from Canadian Rivers between 1972 and 1977 ranged between less than

Table 9 CHROMIUM AND NICKEL LEVELS OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS

METAL**	1981								1982			
	June 23		June 25		September 10		September 11		March 9		March 10	
	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)	$\bar{x}$	(S.D.)
Diss. Cr												
Yakoun R #1	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)
Yakoun R #2	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)
Yakoun R #3	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)
Barbie Cr	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)
Canoe Cr	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)
Florence Cr	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)
Total Cr												
Yakoun R #1	L7.5	(0.0)	9.1	(2.8)	L7.5	(0.0)	L7.5	(0.0)	7.7	(0.3)	8.3	(0.6)
Yakoun R #2	L7.5	(0.0)	9.7	(3.8)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)
Yakoun R #3	L7.5	(0.0)	L7.5	(0.0)	8.3	(1.4)	L7.5	(0.0)	11.3	(6.6)	L7.5	(0.0)
Barbie Cr	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	10.7	(5.5)	L7.5	(0.0)
Canoe Cr	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)	L7.5	(0.0)
Florence Cr	17.3	(16.9)	8.6	(1.8)	L7.5	(0.0)	L7.5	(0.0)	8.3	(1.4)	L7.5	(0.0)
Diss. Ni												
Yakoun R #1	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Yakoun R #2	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Yakoun R #3	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Barbie Cr	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Canoe Cr	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Florence Cr	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Total Ni												
Yakoun R #1	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Yakoun R #2	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Yakoun R #3	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Barbie Cr	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Canoe Cr	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)
Florence Cr	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)	L40	(0.0)

**as ug/l (ppb), n =3.

.2 ug/l to 340 ug/l and approximately 90% of the results were less than 20 ug/l.

For the protection of aquatic life Environment Canada recommended a water quality objective of 40 ug/l as total chromium (30). EPA (21) reported a total recoverable hexavalent chromium criterion to protect freshwater aquatic life of 21 ug/l as a concentration not to be exceeded at any time. Based on water hardness and as examples, the concentration of total recoverable trivalent chromium for a water hardness of 50, 100 and 200 mg/l as $CaCO_3$ should not exceed 2200 ug/l, 4700 ug/l and 9900 ug/l, respectively. Taylor et al (30) reported that hexavalent chromium while not subject to sedimentation reacts strongly with oxidizable substances (usually organic molecules) and forms trivalent chromium. Trivalent chromium has a strong tendency to form stable complexes with negatively charged inorganic or organic species or form colloidal hydrous oxides. Thus, it is very unlikely that much dissolved chromium will be present in aqueous solution (30). Guidelines for drinking water quality recommended a maximum acceptable total chromium concentration of 50 ug/l (24).

Nickel

A change in the detection limit calculation resulted in a lowering of the limit in the March survey to 20 ug/l compared to 40 ug/l in June and September. For consistency, the March levels are reported at the higher detection limit in Table 9.

The total and dissolved nickel concentrations were all below 40 ug/l in June and September and 20 ug/l in March (Appendix I). Taylor et al (31) reported that extractable nickel concentrations in almost 4800 river samples collected across Canada between 1972 and 1977 ranged between less than 1 ug/l and approximately 300 ug/l. Ninety percent of the results were below 12 ug/l.

For the protection of aquatic life, Environment Canada recommended a water quality objective for total nickel of 25 ug/l in soft water and 250 ug/l in water of hardness greater than 150 mg/l as $CaCO_3$ (31).

EPA (21) reported a total recoverable nickel criterion to protect freshwater aquatic life and as examples, the concentration based on a hardness of 50, 100 and 200 mg/l as $CaCO_3$ should not exceed 1100 ug/l, 1800 ug/l and 3100 ug/l respectively, at any time. The 24-hour average concentrations, for example, at a hardness of 50, 100 and 200 mg/l as $CaCO_3$ should not exceed 56 ug/l, 96 ug/l and 160 ug/l respectively (21).

5.1.2.5 Total and Dissolved Selenium, Aluminium, Iron and Manganese.

Selenium

Mean total and dissolved selenium concentrations were all below the 0.5 ug/l detection limit (Table 10).

Environment Canada (32) recommended a water quality objective for the protection of aquatic life of 10 ug/l total selenium until further research has been done. EPA (21) reported a total recoverable inorganic selenite criterion to protect freshwater aquatic life of 35 ug/l as a 24-hour average and the concentration should not exceed 260 ug/l at anytime. Guidelines for drinking water quality recommended a maximum acceptable total selenium concentration of 10 ug/l (24).

Aluminium

Mean total and dissolved aluminium concentrations are reported in Table 10. McNeely et al (37) reported that most natural waters contain less than 1000 ug/l aluminium although acidic waters may contain higher concentrations. No Canadian guidelines for aluminium have been established to protect aquatic biota but a tentative limit of 100 ug/l has been proposed (37). Aluminium was not listed in the EPA Water Quality criteria document (21).

Iron

Mean total and dissolved iron concentrations are reported in Table 11. McKee and Wolf (15) reported that of the waters that support good fish

Table 10 SELENIUM AND ALUMINIUM LEVELS OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS

METAL**	1981								1982			
	June 23		June 25		September 10		September 11		March 9		March 10	
	x	(S.D.)	x	(S.D.)	x	(S.D.)	x	(S.D.)	x	(S.D.)	x	(S.D.)
Diss. Se												
Yakoun R #1	-		-		L.5	(0.0)	L.5	(0.0)	L.5	(0.0)	L.5	(0.0)
Yakoun R #2	-		-		L.5	(0.0)	L.5	(0.0)	L.5	(0.0)	L.5	(0.0)
Yakoun R #3	-		-		L.5	(0.0)	L.5	(0.0)	L.5	(0.0)	L.5	(0.0)
Barbie Cr	-		-		L.5	(0.0)	L.5	(0.0)	L.5	(0.0)	L.5	(0.0)
Canoe Cr	-		-		L.5	(0.0)	L.5	(0.0)	L.5	(0.0)	L.5	(0.0)
Florence Cr	-		-		L.5	(0.0)	L.5	(0.0)	L.5	(0.0)	L.5	(0.0)
Total Se												
Yakoun R #1	-		-		L.5	(0.0)	L.5	(0.0)	L.5	(0.0)	L.5	(0.0)
Yakoun R #2	-		-		L.5	(0.0)	L.5	(0.0)	L.5	(0.0)	L.5	(0.0)
Yakoun R #3	-		-		L.5	(0.0)	L.5	(0.0)	L.5	(0.0)	L.5	(0.0)
Barbie Cr	-		-		L.5	(0.0)	L.5	(0.0)	L.5	(0.0)	L.5	(0.0)
Canoe Cr	-		-		L.5	(0.0)	L.5	(0.0)	L.5	(0.0)	L.5	(0.0)
Florence Cr	-		-		L.5	(0.0)	L.5	(0.0)	L.5	(0.0)	L.5	(0.0)
Diss. Al												
Yakoun R #1	88	(7)	66	(4)	134	(3)	215	(3)	-		-	
Yakoun R #2	79	(6)	77	(2)	144	(17)	234	(17)	-		-	
Yakoun R #3	148	(9)	196	(6)	220	(11)	188	(6)	-		-	
Barbie Cr	346	(5)	435	(5)	435	(14)	440	(1)	-		-	
Canoe Cr	536	(7)	621	(6)	620	(1)	550	(4)	-		-	
Florence Cr	466	(8)	541	(4)	572	(7)	522	(3)	-		-	
Total Al												
Yakoun R #1	154	(58)	91	(36)	394	(69)	1093	(72)	-		-	
Yakoun R #2	170	(70)	138	(33)	433	(108)	1577	(30)	-		-	
Yakoun R #3	207	(31)	264	(21)	634	(34)	3197	(280)	-		-	
Barbie Cr	623	(24)	615	(39)	602	(36)	820	(260)	-		-	
Canoe Cr	598	(63)	729	(28)	850	(92)	969	(136)	-		-	
Florence Cr	578	(54)	708	(105)	681	(54)	997	(50)	-		-	

**as ug/l (ppb), n = 3

Table 11 IRON AND MANGANESE LEVELS OF THE YAKOUN RIVER AND THREE TRIBUTARY STREAMS

METAL**	1981								1982			
	June 23		June 25		September 10		September 11		March 9		March 10	
	x	(S.D.)	x	(S.D.)	x	(S.D.)	x	(S.D.)	x	(S.D.)	x	(S.D.)
Diss. Fe												
Yakoun R #1	229	(3)	193	(7)	212	(4)	268	(17)	155	(5)	154	(2)
Yakoun R #2	261	(52)	220	(13)	235	(3)	289	(7)	100	(3)	167	(2)
Yakoun R #3	324	(2)	419	(2)	348	(10)	287	(11)	232	(1)	255	(28)
Barbie Cr	1062	(95)	1510	(17)	1133	(21)	1213	(31)	441	(4)	482	(3)
Canoe Cr	1017	(39)	1430	(17)	1260	(10)	1133	(6)	658	(5)	585	(0.0)
Florence Cr	935	(8)	1163	(26)	1133	(21)	1070	(10)	542	(1)	515	(2)
Total Fe												
Yakoun R #1	344	(228)	262	(65)	323	(37)	1012	(41)	288	(22)	487	(15)
Yakoun R #2	493	(225)	411	(62)	340	(28)	1437	(83)	275	(4)	508	(16)
Yakoun R #3	488	(144)	588	(24)	633	(77)	3500	(257)	436	(25)	397	(6)
Barbie Cr	2563	(83)	2376	(229)	1223	(21)	1367	23)	550	(16)	595	(7)
Canoe Cr	1240	(191)	1560	(92)	1397	(21)	1443	(42)	751	(4)	618	(58)
Florence Cr	1383	(344)	1513	(160)	1197	(21)	1283	(15)	628	(23)	677	(5)
Diss. Mn												
Yakoun R #1	13	(.6)	11	(.6)	13	(0.0)	18	(.6)	11	(0.0)	10	(.6)
Yakoun R #2	14	(1.1)	14	(.6)	18	(.6)	22	(.6)	14	(0.0)	15	(.6)
Yakoun R #3	18	(0.0)	22	(0.0)	23	(.6)	22	(1.1)	17	(0.0)	19	(1.1)
Barbie Cr	67	(1.1)	69	(.6)	27	(0.0)	25	(.6)	92	(.6)	87	(.6)
Canoe Cr	30	(.6)	35	(0.0)	71	(.6)	62	(.6)	35	(0.0)	34	(0.0)
Florence Cr	23	(0.0)	26	(.6)	48	(.6)	40	(.6)	20	(0.0)	21	(.6)
Total Mn												
Yakoun R #1	16	(.6)	15	(.6)	36	(1.7)	71	(1.7)	14	(0.0)	27	(.6)
Yakoun R #2	16	(4.6)	19	(.6)	41	(2.3)	91	(4.2)	17	(.6)	28	(1.1)
Yakoun R #3	25	(0.0)	27	(1.0)	62	(4.2)	304	(11.0)	23	(1.0	23	(0.0)
Barbie Cr	93	(.6)	89	(1.0)	278	(3.0)	254	(2.6)	94	(1.5)	88	(1.5)
Canoe Cr	35	(1.7)	39	(1.1)	77	(1.1)	73	(1.7)	37	(.6)	33	(3.8)
Florence Cr	32	(4.4)	33	(2.1)	58	(1.1)	57	(.6)	23	(1.0)	27	(.6)

**as ug/l (ppb), n = 3

fauna in the United States, 50% have iron concentrations $\leq$ 300 ug/l and 95% have iron concentrations $\leq$ 700 ug/l. McNeely et al (37) reported that concentrations of iron in aerated surface waters are usually less than 500 ug/l. On that basis it would appear Barbie Creek, Canoe Creek and Florence Creek all have high total and dissolved iron levels with concentrations in excess of 1000 ug/l in June and September, 1981.

Comparing September 10 to September 11, 1981 the influence of increased surface runoff on the total iron concentration can be seen on the Yakoun River stations and particularily Yakoun R#3 were mean total iron increased from 633 ug/l to 3500 ug/l (Table 11). A comparable increase did not occur for dissolved iron indicating the iron was in a particulate form $\leq$ 0.45 um. A comparable elevation due to surface runoff was not evident for the three creeks.

Sigma (33) reported that for the use of surface waters in fish culture, if elevated iron levels are found and if particulate matter appears to be potentially troublesome, pilot hatchery or long term bioassay work may be required to establish the suitability of the watercourse. Guidelines for drinking water quality recommend a maximum acceptable iron concentration of 300 ug/l based on aesthetic considerations (24).

Manganese

Mean total and dissolved manganese concentrations are reported in Table 11. Thurston et al (9) reported that manganese is rarely a problem in freshwater when compared to toxic metals like mercury, lead, cadmium, copper and zinc, and often the factors responsible for the increase in manganese (low pH or dissolved oxygen) may be more toxic to aquatic life than manganese itself. Sigma (33) reported that there is presently insufficient information available on the effects of either ionic or particulate manganese on fish culture to develop satisfactory criteria. McNeely et al (37) reported that manganese seldom reaches concentrations of 1000 ug/l in natural surface waters and is usually present in concentrations of 200 ug/l or less.

Guidelines for drinking water quality recommended a maximum acceptable manganese concentration of 50 ug/l based on aesthetic considerations (24).

REFERENCES

1. Fyles, J.T., Procedures for Obtaining Approval of Metal Mine Development. Prepared by Ministry of Energy, Mines and Petroleum Resources (1979).

2. Fanning, M.L., and T.C. Griffing, Stage I Submission to Steering Committee for Development of New Metal Mines. Prepared for Consolidated Cinola Mines Ltd. by IEC Consultants (1980).

3. WSC, Historical Streamflow Summary to 1979. Inland Waters Directorate, Ottawa (1980).

4. WSC, Surface Water Data 1980. Inland Waters Directorate, Ottawa (1981).

5. WSC, Surface Water Data 1981. Inland Waters Directorate, Ottawa (1982).

6. Laboratory Manual, Department of Environment and Department of Fisheries and Oceans (Pacific Region) (1979).

7. Oguss, E., and W.E. Erlebach. Limitations of Single Water Samples in Representing Mean Water Quality. Inland Waters Directorate, Pacific and Yukon Region, Technical Bulletin No. 95 (1976).

8. APHA-AWWA-WPCF, Standard Methods for the Examination of water and Wastewater - 14th Ed., American Public Health Association (1976).

9. Thurston, R.V., R.C. Russo, C.M. Fetterolf Jr., T.A. Edsall and Y.M. Barber Jr. (Eds.). A Review of the EPA Red Book: Quality Criteria for Water. Water Quality Section, American Fisheries Society, Bethesda, MD. 313 p (1979).

10. EPA, Water Quality Criteria 1972. A Report of the Committee on Water Quality Criteria. EPA R3 73 033, March (1973).

11. EPA, Quality Criteria for Water. Office of Water and Hazardous Materials, U.S. Environmental Protection Agency, Washington, D.C., (1977).

12. Neubecker, T.A. and H.E. Allen. The Measurement of Complexation Capacity and Conditional Stability Constants for Ligands in Natural Waters. Water REs. 17, 1-14, (1983).

13. Schnitzer, M. The Chemistry of Humic Substances. Environmental Biogeochemistry, Vol. 1. Ed. by J.O. Nriagu, Ann Arbos Science, 89-115, (19).

14. APHA-AWWA-WCPF. Standard Methods for the Examination of Water and Wastewater - 15th Ed., American Public Health Association, (1981).

15. McKee, J.E. and H.W. Wolf (Eds.), Water Quality Criteria. California State Water Resources Control Board, Publications 3-A, 2nd edition, (1963).

16. Laxen, D.P.H. and R.M. Harrison. The Physiochemical Speciation of Cd, Pb, Cu, Fe and Mn in the Final Effluent of a Sewage Treatment Works and its Impact on Speciation in the Receiving River. Water Res. 15, 1053-1065, (1981).

17. Laxen, D.P.H. and R.M. Harrison. A Scheme for the Physio-Chemical Speciation of Trace Metals in the Environment. Sci. Tot. Envir. 19, 59-82, (1981).

18. Florence, T.M., Trace Metal Species in Fresh Waters. Water Res. 11, 681-687, (1977).

19. Danielsson, L.G. On the Use of Filters for Distinguishing Between Dissolved and Particulate Fractions in Natural Waters. Water RES. 16, 179-182, (1982).

20. Garrett, C.L., L.A. MacLeod and H.J. Sneddon. Mercury in the British Columbia and Yukon Environments. Summary of Data to January 1, 1979. Environmental Protection Service, Pacific Region, Regional Program Report 80-4, (1980).

21. EPA, Federal Register Part V, Water Quality Criteria Documents, Vol. 45, No. 231, 79318-79379, November 28 (1980).

22. Federal Register. Water Quality Criteria Corrections. Vol. 46, No. 156, August 13, 1981, pg. 40919, (1981).

23. Reeder, S.W., A. Demayo and M.C. Taylor. Guidelines for Surface Water Quality-Mercury. In Vol. 1 Inorganic Chemical Substances. Inland Waters Directorate, Water Quality Branch, Ottawa, Canada, (1979).

24. N.H.W. Guidelines for Canadian Drinking Waters Quality 1978. Prepared by the Federal-Provincial Working Group on Drinking Water, Canadian Government Publishing Centre, Catalogue no. H48-10/1978.

25. Demayo, A., M.C. Taylor and S.W. Reeder. Guidelines for Surface Wter Quality-Arsenic. In Vol. 1 Inorganic Chemical Substances. Inland Waters Directorate, Water Quality Branch, Ottawa, Canada, (1979).

26. Demayo, A., M.C. Taylor and S.W. Reeder. Guidelines for Surface Water Quality-Lead. In Vol. 1 Inorganic Chemical Substances. Inland Waters Directorate, Water Quality Branch, Ottawa Canada, (1980).

27. Taylor, M.C., and A. Demayo. Guidelines for Surface Water Quality-Zinc. In Vol. 1 Inorganic Chemical Substances. Inland Waters Directorate, Water Quality Branch, Ottawa, Canada, (1980).

28. Reeder, S.W., A.D. Demayo and M.C. Taylor. Guidelines for Surface Water Quality-Cadmium. In Vol. 1 Inorganic Chemical Substances. Inland Waters Directorate, Water Quality Branch, Ottawa, Canada, (1980).

29. Demayo, A. and M.C. Taylor. Guidelines for Surface Water Quality-Copper. In Vol. 1 Inorganic Chemical Substances. Inland Waters Directorate, Water Quality Branch, Ottawa, Canada, (1981).

30. Taylor, M.C., S.W. Reeder and A. Demayo. Guidelines for Surface Water Quality - Chromium. In Vol. 1 Inorganic Chemical Substances. Inland Waters Directorate, Water Quality Branch, Ottawa, Canada (1979).

31. Taylor, M.C., A. Demayo and S.W. Reeder. Guidelines for Surface Water Quality - Nickel. In Vol. 1 Inorganic Chemical Substances. Inland Waters Directorate, Water Quality Branch, Ottawa, Canada (1979).

32. Demayo, A., M.C. Taylor and S.W. Reeder. Guidelines for Surface Water Quality - Selenium. In Vol. 1 Inorganic Chemical Substances. Inland Waters Directorate, Water Quality Branch, Ottawa, Canada (1979).

33. Sigma Resource Consultants. Summary of Water Quality Criteria for Salmonid Hatcheries. Prepared for Department of Fisheries and Oceans (1979).

34. Reeder, S.W. Guidelines for Surface Water Quality - Preamble. In Vol. 1 Inorganic Chemical Substances. Inland Waters Directorate, Water Quality Branch, Ottawa, Canada (1979).

35. EPA. Methods for Chemical Analysis of Water and Wastes. Environmental Monitoring and Support Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Cincinnati, Ohio (1979).

36. Forstner, U. and G.T.W. Wittman. Metal Pollution in the Aquatic Environment. Springer-Verlag, New York (1979).

37. McNeely, R.N., V.P. Neimanis and L. Dwyen. Water Quality Source Book - A Guide to Water Quality Parameters. Inland Waters Directorate, Water Quality Branch, Ottawa, Canada (1979).

ACKNOWLEDGEMENTS

The help and local information provided by Mr. J. Turbuck and Mr. J. Lamb with the Department of Fisheries was appreciated.

Thanks are extended to Mr. M. Jones for field support, Mrs. L. Pearson for drafting, Mr. L. McLeod for computer assistance and the staff of the Environmental Protection Service laboratory for chemical analyses.

Thanks are extended to Mr. B. Kelso for reviewing this manuscript.

APPENDIX I

RECEIVING WATER QUALITY DATA FOR HEAVY METALS - YAKOUN RIVER AND THREE TRIBUTARY STREAMS

APPENDIX I CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Total Mercury* - ug/l)

SAMPLE DATE - 1981

Station	June 23			June 25			September 10			September 11			March 9			March 10		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River																		
Station 1	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.7	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Station 2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Station 3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.3	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Barbie Creek																		
Station 4	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Canoe Creek																		
Station 5	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	0.23	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2
Florence Creek																		
Station 6	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2	< 0.2

* detection limit 0.2 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Total Arsenic* - ug/l)

SAMPLE DATE - 1981

Station	June 23			June 25			September 10			September 11			March 9			March 10		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River																		
Station 1							0.6	< 0.5	< 0.5	0.6	0.7	0.5	< 0.5	1.0	< 0.5	< 0.5	< 0.5	< 0.5
Station 2							< 0.5	< 0.5	< 0.5	0.7	0.7	0.7	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Station 3							< 0.5	< 0.5	< 0.5	1.6	1.8	1.7	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Barbie Creek																		
Station 4							1.8	2.3	1.9	2.0	2.0	2.0	< 0.5	< 0.5	< 0.5	< 0.5	0.6	< 0.5
Canoe Creek																		
Station 5							0.6	0.6	< 0.5	0.6	0.9	0.5	< 0.5	0.9	< 0.5	< 0.5	< 0.5	< 0.5
Florence Creek																		
Station 6							< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	1.2	< 0.5	< 0.5	< 0.5

* detection limit 0.5 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Dissolved Arsenic* - ug/l)

SAMPLE DATE - 1981

Station	June 23			June 25			September 10			September 11			March 9			March 10		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River																		
Station 1							< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Station 2							< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Station 3							< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	1.1	< 0.5	< 0.5
Barbie Creek																		
Station 4							1.2	1.1	1.1	1.1	1.1	1.1	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Canoe Creek																		
Station 5							< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5
Florence Creek																		
Station 6							< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5	< 0.5

* detection limit 0.5 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Total Lead* - ug/l)

SAMPLE DATE - 1981

Station	June 23			June 25			September 10			September 11		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Station 2	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Station 3	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Barbie Creek												
Station 4	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Canoe Creek												
Station 5	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Florence Creek												
Station 6	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40

* detection limit 40 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Total Lead* - ug/l)

SAMPLE DATE - 1982

Station	March 9			March 10			March 9**			March 10**		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 40	< 40	< 40	< 40	40	< 40	20	20	20	30	40	20
Station 2	40	< 40	< 40	< 40	< 40	< 40	40	20	< 20	< 20	30	30
Station 3	< 40	< 40	< 40	< 40	40	< 40	< 20	< 20	< 20	30	40	30
Barbie Creek												
Station 4	< 40	< 40	40	< 40	< 40	< 40	< 20	20	40	30	30	< 20
Canoe Creek												
Station 5	< 40	< 40	40	< 40	< 40	< 40	< 20	< 20	40	< 20	< 20	20
Florence Creek												
Station 6	< 40	40	< 40	< 40	< 40	< 40	30	40	30	< 20	< 20	< 20

* detection limit 40 ug/l

**detection limit 20 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Dissolved Lead* - ug/l)

SAMPLE DATE - 1981

Station	June 23			June 25			September 10			September 11		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Station 2	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Station 3	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Barbie Creek												
Station 4	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Canoe Creek												
Station 5	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Florence Creek												
Station 6	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40

* detection limit 40 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Dissolved Lead* - ug/l)

SAMPLE DATE - 1982

Station	March 9			March 10			March 9**			March 10**		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20
Station 2	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20
Station 3	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20
Barbie Creek												
Station 4	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20
Canoe Creek												
Station 5	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20
Florence Creek												
Station 6	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20

*detection limit 40 ug/l

**detection limit 20 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Total Zinc* - ug/l)

SAMPLE DATE - 1981

Station	June 23			June 25			September 10			September 11		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	10	19	20	20
Station 2	< 5	< 5	8	< 5	6	< 5	7	< 5	< 5	146	64	50
Station 3	< 5	7	6	< 5	< 5	12	< 5	6	< 5	58	86	418
Barbie Creek												
Station 4	< 5	6	6	5	< 5	< 5	112	32	61	139	26	106
Canoe Creek												
Station 5	< 5	< 5	< 5	12	< 5	< 5	11	< 5	< 5	297	22	21
Florence Creek												
Station 6	< 5	< 5	< 5	28	5	< 5	< 5	5	< 5	55	205	44

* detection limit 5 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Total Zinc* - ug/l)

SAMPLE DATE - 1982

Station	March 9			March 10			March 9**			March 10**		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	5	< 5	< 5	< 5	6	5	5	3	3	4	6	5
Station 2	5	< 5	< 5	< 5	5	< 5	5	4	< 2	3	5	3
Station 3	< 5	< 5	< 5	< 5	< 5	< 5	2	< 2	< 2	< 2	4	4
Barbie Creek												
Station 4	9	10	8	7	9	9	9	10	8	7	9	9
Canoe Creek												
Station 5	5	< 5	5	< 5	9	< 5	5	2	5	2	9	3
Florence Creek												
Station 6	< 5	< 5	< 5	< 5	< 5	< 5	4	< 2	3	3	4	2

*detection limit 5 ug/l

**detection limit 2 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Dissolved Zinc* - ug/l)

SAMPLE DATE - 1981

Station	June 23			June 25			September 10			September 11		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	7	7	6
Station 2	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	6	6	7
Station 3	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	6	7	6
Barbie Creek												
Station 4	< 5	< 5	< 5	< 5	< 5	< 5	12	13	13	17	20	17
Canoe Creek												
Station 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	8	8	6
Florence Creek												
Station 6	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	6	8	7

* detection limit 5 ug/l

APPENDIX I CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Dissolved Zinc* - ug/l)

SAMPLE DATE - 1982

Station	March 9			March 10			March 9**			March 10**		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun iver												
Station 1	22	< 5	< 5	< 5	< 5	< 5	22	< 2	< 2	< 2	< 2	< 2
Station 2	< 5	< 5	< 5	< 5	< 5	< 5	< 2	< 2	< 2	< 2	< 2	< 2
Station 3	< 5	< 5	< 5	< 5	< 5	< 5	< 2	< 2	< 2	< 2	< 2	< 2
Barbie Creek												
Station 4	< 5	7	< 5	5	5	7	3	7	3	5	5	7
Canoe Creek												
Station 5	< 5	< 5	< 5	< 5	< 5	< 5	< 2	< 2	< 2	< 2	< 2	< 2
Florence Creek												
Station 6	< 5	< 5	< 5	< 5	< 5	< 5	< 2	< 2	< 2	< 2	< 2	< 2

*detection limit 5 ug/l

**detection limit 2 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Total Cadmium* - ug/l)

SAMPLE DATE - 1981

Station	June 23			June 25			September 10			September 11		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Station 2	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Station 3	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Barbie Creek												
Station 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Canoe Creek												
Station 5	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Florence Creek												
Station 6	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4

* detection limit 4 ug/l

APPENDIX I CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Total Cadmium* - ug/l)

SAMPLE DATE - 1982

Station	March 9			March 10			March 9**			March 10**		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 4	< 4	< 4	< 4	< 4	< 4	< 2	< 2	< 2	< 2	3	< 2
Station 2	< 4	< 4	< 4	< 4	< 4	< 4	< 2	< 2	< 2	< 2	< 2	< 2
Station 3	< 4	< 4	< 4	< 4	< 4	< 4	< 2	< 2	< 2	< 2	3	< 2
Barbie Creek												
Station 4	< 4	< 4	< 4	< 4	< 4	< 4	< 2	< 2	2	< 2	< 2	< 2
Canoe Creek												
Station 5	< 4	< 4	< 4	< 4	< 4	< 4	< 2	< 2	< 2	< 2	< 2	< 2
Florence Creek												
Station 6	< 4	< 4	< 4	< 4	< 4	< 4	< 2	2	2	< 2	< 2	< 2

*detection limit 4 ug/l

**detection limit 2 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Dissolved Cadmium* - ug/l)

SAMPLE DATE - 1981

Station	June 23			June 25			September 10			September 11		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Station 2	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Station 3	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Barbie Creek												
Station 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Canoe Creek												
Station 5	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4
Florence Creek												
Station 6	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4	< 4

* detection limit 4 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Dissolved Cadmium* - ug/l)

SAMPLE DATE - 1982

Station	March 9			March 10			March 9**			March 10**		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 4	< 4	< 4	< 4	< 4	< 4	< 2	< 2	< 2	< 2	< 2	< 2
Station 2	< 4	< 4	< 4	< 4	< 4	< 4	< 2	< 2	< 2	< 2	< 2	< 2
Station 3	< 4	< 4	< 4	< 4	< 4	< 4	< 2	< 2	< 2	< 2	< 2	< 2
Barbie Creek												
Station 4	< 4	< 4	< 4	< 4	< 4	< 4	< 2	< 2	< 2	< 2	< 2	< 2
Canoe Creek												
Station 5	< 4	< 4	< 4	< 4	< 4	< 4	< 2	< 2	< 2	< 2	< 2	< 2
Florence Creek												
Station 6	< 4	< 4	< 4	< 4	< 4	< 4	< 2	< 2	< 2	< 2	< 2	< 2

*detection limit 4 ug/l

**detection limit 2 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Total Copper* - ug/l)

SAMPLE DATE - 1981

Station	June 23			June 25			September 10			September 11			March 9			March 10		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River																		
Station 1	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	6	< 5	< 5	5	5	6
Station 2	< 5	< 5	< 5	< 5	27	< 5	< 5	< 5	< 5	< 5	< 5	< 5	6	< 5	< 5	< 5	< 5	< 5
Station 3	< 5	< 5	< 5	< 5	< 5	6	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	7	< 5
Barbie Creek																		
Station 4	< 5	< 5	32	9	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	6	6	8	< 5
Canoe Creek																		
Station 5	< 5	< 5	< 5	< 5	32	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	5	7	6
Florence Creek																		
Station 6	6	< 5	< 5	< 5	29	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	6	7	< 5	5	8

* detection limit 5 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Dissolved Copper* - ug/l)

SAMPLE DATE - 1981

Station	June 23			June 25			September 10			September 11			March 9			March 10		
	Replicate			Replicate			Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River																		
Station 1	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	6	< 5	< 5	< 5	< 5	< 5
Station 2	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Station 3	< 5	< 5	< 5	< 5	< 5	< 5	< 5	8	11	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Barbie Creek																		
Station 4	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Canoe Creek																		
Station 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5
Florence Creek																		
Station 6	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5	< 5

* detection limit 5 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Total Chromium* - ug/l)

SAMPLE DATE - 1981

Station	June 23			June 25			September 10			September 11		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 7.5	< 7.5	< 7.5	< 7.5	12.3	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5
Station 2	< 7.5	< 7.5	< 7.5	14.1	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5
Station 3	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	9.9	< 7.5	< 7.5	< 7.5	< 7.5
Barbie Creek												
Station 4	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5
Canoe Creek												
Station 5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5
Florence Creek												
Station 6	< 7.5	36.8	< 7.5	10.7	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5

* detection limit 7.5 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Total Chromium* - ug/l)

SAMPLE DATE - 1982

Station	March 9			March 10			March 9**			March 10**		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 7.5	< 7.5	8	9	8	8	7	< 5	8	9	8	8
Station 2	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 5	< 5	< 5	< 5	7	6
Station 3	19	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	19	< 5	< 5	5	7	6
Barbie Creek												
Station 4	< 7.5	< 7.5	17	< 7.5	< 7.5	< 7.5	5	< 5	17	< 5	6	< 5
Canoe Creek												
Station 5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 5	< 5	5	< 5	< 5	< 5
Florence Creek												
Station 6	< 7.5	10	< 7.5	< 7.5	< 7.5	< 7.5	< 5	10	7	7	7	< 5

*detection limit 7.5 ug/l

**detection limit 5 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Dissolved Chromium* - ug/l)

SAMPLE DATE - 1981

Station	June 23			June 25			September 10			September 11		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5
Station 2	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5
Station 3	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5
Barbie Creek												
Station 4	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5
Canoe Creek												
Station 5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5
Florence Creek												
Station 6	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5

* detection limit 7.5 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Total Chromium* - ug/l)

SAMPLE DATE - 1982

Station	March 9			March 10			March 9**			March 10**		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 5	< 5	< 5	< 5	< 5	< 5
Station 2	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 5	< 5	< 5	< 5	< 5	< 5
Station 3	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 5	< 5	< 5	< 5	< 5	< 5
Barbie Creek												
Station 4	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 5	< 5	< 5	< 5	< 5	< 5
Canoe Creek												
Station 5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 5	< 5	< 5	< 5	< 5	< 5
Florence Creek												
Station 6	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 7.5	< 5	< 5	< 5	< 5	< 5	< 5

*detection limit 7.5 ug/l

**detection limit 5 ug/l

APPENDIX I CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Total Nickel* - ug/l)

SAMPLE DATE - 1981

Station	June 23			June 25			September 10			September 11		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Station 2	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Station 3	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Barbie Creek												
Station 4	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Canoe Creek												
Station 5	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Florence Creek												
Station 6	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40

* detection limit 40 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Total Nickel* - ug/l)

SAMPLE DATE - 1982

Station	March 9			March 10			March 9**			March 10**		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20
Station 2	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20
Station 3	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20
Barbie Creek												
Station 4	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20
Canoe Creek												
Station 5	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20
Florence Creek												
Station 6	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20

* detection limit 40 ug/l

**detection limit 20 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Dissolved Nickel* - ug/l)

SAMPLE DATE - 1981

Station	June 23			June 25			September 10			September 11		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Station 2	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Station 3	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Barbie Creek												
Station 4	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Canoe Creek												
Station 5	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40
Florence Creek												
Station 6	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40	< 40

* detection limit 40 ug/l

APPENDIX I

CONSOLIDATED CINOLA - RECEIVING WATER QUALITY DATA

Parameter (Dissolved Nickel* - ug/l)

SAMPLE DATE - 1982

Station	March 9			March 10			March 9**			March 10**		
	Replicate			Replicate			Replicate			Replicate		
	1	2	3	1	2	3	1	2	3	1	2	3
Yakoun River												
Station 1	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20
Station 2	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20
Station 3	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20
Barbie Creek												
Station 4	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20
Canoe Creek												
Station 5	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20
Florence Creek												
Station 6	< 40	< 40	< 40	< 40	< 40	< 40	< 20	< 20	< 20	< 20	< 20	< 20

* detection limit 40 ug/l

**detection limit 20 ug/l

POOR

QUALITY

ORIGINAL